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STANDARDS FOR MEASURING THE EFFICIENCY OF EXHAUST SYSTEMS IN POLISHING SHOPS.

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Standards of Air Dustiness.

From the standpoint of the sanitarian and public health official, the influence of dusty trades on health is largely dependent on the character of the dust. The industrial dusts with which the present study is concerned are those which are injurious by virtue of their physical properties and their mechanical irritant action rather than because of chemical toxicity or bacterial content.

The protection of workers against such dusts can sometimes be attained by the substitution of wet for dry processes and sometimes by accomplishing sorting or abrading operations by the use of mechanical devices in inclosed spaces. In certain extreme cases, as in the sand-blasting of large castings, the wearing of special respirators or helmets is the only practicable safeguard. In most dust-generating processes, however, and notably in the operation of grinding and buffing wheels, the removal of the dust at its point of production by a powerful system of local exhaust ventilation is the most effective safeguard.

Many State laws deal with this problem, but until recently the provisions they contain have been very general in their nature. Seven years ago Hoffman (1911) reviewed the state of existing legislation as follows:

"Ten States make special mention of dusts from emery wheels or other metallic substances. Except in five States (Illinois, Michigan, New Jersey, Ohio, and Wisconsin) the laws require merely that injurious dusts are to be removed 'as far as practicable' or 'as far as the nature of the business permits', or 'when inhaled to an injurious extent'; and the entire decision as to the kind of protective device necessary is left to the discretion of the inspection officials. In the five States mentioned the laws are more specific in that they carefully

define the character of the appliances to be installed and place the duty of installation directly upon the employer. In Michigan and in Illinois under the 1905 act, which was not repealed by the law of 1909, however, the inspector may not enforce the provisions of the law unless complaint has been made by some person, and in Illinois the complaint must be accompanied by $1. Twenty-eight States and the District of Columbia have no specific legal enactment for the protection of workers from injurious dusts, although several of these have general provisions with reference to ventilation."

Since 1911 several States have adopted, usually through industrial commissions or industrial boards, more specific and definite standards for dust removal. So far as we are aware those regulations all depend on the establishment of a minimum static suction head in the exhaust ducts connected with grinding, polishing, and buffing wheels.

Thus, according to the Wisconsin Code—

"On all grinding, buffing, and polishing wheels, the suction in the connection to the hood must be sufficient to displace a column of water in a U tube, 5 inches.

"The test for suction with the U tube must be a static test and must be made in the following manner: A hole $\frac{1}{8}$ inch in diameter must be made in the suction pipe approximately 12 inches from the connection to the hood. The rubber hose attached to the U tube must be placed over the $\frac{1}{8}$-inch hole and the test made under these conditions. When the water in the U tube stands at 0, the 5-inch displacement is secured when one column of water rises $2\frac{1}{2}$ inches above 0 and the other column of water falls $2\frac{1}{2}$ inches below 0."

The New Jersey code requires that—

"Sufficient suction head shall be maintained in each branch pipe within 15 inches of the hood to displace 2 inches of water in a U-shaped tube. Pressure to be taken by pressing tube attachment over small opening through pipe, commonly called static method. Tests to be made with all branches open and unobstructed."

The New York code reads:

"Sufficient static suction shall be maintained in every branch pipe within 1 foot of the hood to produce a difference of level of at least 2 inches of water between the two sides of a U-shaped tube. Test shall be made placing one end of a rubber tube over a small hole made in pipe, the other end of tube being connected to one side of U-shaped water gauge. Such test shall be made with all branch pipes open and unobstructed."

The head, as thus measured, includes both velocity and frictional components, and it is obvious that it bears no necessary relation to the velocity of the exhaust at the face of the wheel itself. The State codes, to which reference has been made, do, it is true, specify the

size of the exhaust piping to be installed for a wheel of any given size, but the form of the hood and its arrangement in relation to the grinding process will materially affect the results obtained, while any obstruction to air flow between the wheel and the point where the suction head is measured will reduce the actual efficiency obtained with a given suction head. For example, in a certain polishing shop studied by us the exhaust was effected through a 10 by 6 inch opening in the machine table directly below the wheel. In these openings were placed screens of wire mesh, some with nine-sixteenths inch meshes and others with one-fourth inch meshes. The fine mesh screens were many of them badly clogged with lint and other forms of dirt. With the same suction head in the exhaust pipe, the velocity through the 10 by 6 inch opening without any screen was 900 feet per minute; with a fairly clean coarse screen (A, fig. 1) it was 860 feet; with a badly clogged fine screen (B, fig. 1) it was only 500 feet.

For such reasons the standard which depends only on suction head in the exhaust pipe seems to us very inadequate as a measure of the actual protection afforded to the worker, and the difference between the New York and New Jersey standards of 2 inches and the Wisconsin standard of 5 inches indicates that the evidence upon which even this imperfect standard has been based must be somewhat inconclusive.

A more valuable sort of standard from the sanitary standpoint would be one based on actual velocity of exhaust at the point of dust production, instead of suction head in the duct below. Such a standard was suggested by the British departmental committee on the lead hazard in the pottery industry (Great Britain, 1910) in the form of the very mild recommendation that a speed of 100 linear feet per minute should be maintained at the point of dust production.

The only standard that can be altogether satisfactory to the sanitarian, however, is one that deals directly with the actual condition of the air inhaled by the worker. It is well that certain definite suction heads and air velocities should be maintained, but what we really want to know is whether the dust has actually been removed. Mechanical standards are convenient and easy of application, but whenever special conditions interfere with such correlation it is the actual state of the atmosphere that is of primary importance. What we must ultimately rely upon in the future is a standard that rests upon the number or weight of dust particles actually contained in the air breathed by the worker.

So far as we are aware only two efforts have so far been made to set definite standards of this kind for industrial dusts, both of them in connection with the air of mines.

The earliest of these attempts was made by the miners' phthisis prevention committee of South Africa (1916), and reference to their

report (p. 21) shows that they were fully cognizant of the difficulty and the novelty of the problem. To quote:

"69. The committee, being desirous of taking immediate steps to cope with the disease, was confronted with the difficulty that no standard of purity with regard to dust existed to which to work. In order to assist in arriving at such a standard, tests of the amount and the character of the dust in the street air of Johannesburg were taken as affording some basis of comparison. At the same time it was soon discovered by experiment that it was practically impossible to remove by dust-allaying devices all the dust from either underground or surface air. The question arose as to what weight per cubic meter could be considered permissible, and as this was more or less a matter for conjecture the committee decided, for the time being, to adopt the tentative standard of 5 milligrams of dust to the cubic meter of air. This figure was at the time supposed to represent the average amount of silicious dust under 70 microns diameter present in the air of a Johannesburg street, but on account of the great difference in character and the proportion of 'injurious' dust between mine and street dust, the direct comparison of weights may be misleading.

"The amount of 'injurious' dust which air can carry without being dangerous has not yet been determined, and, indeed, can only be ascertained by experience."

The only other attempt to set a standard for the dust content of air was made by Higgins, Lanza, Laney, and Rice (1917) in their very complete study of the mines in the Joplin district (Missouri). They say:

"The most reasonable standard then appears to be one based on the quantity of dust that will remain in suspension after the best known methods have been put into use for its abatement.

"It has been demonstrated in the sheet ground mines of the Joplin district that by the proper use of water and the regulation of certain details of mining the quantity of dust in the mine air can be kept below 1 milligram per 100 liters of air; so it seems reasonable to use 1 milligram as a standard at least for the Joplin district."

No similar studies have, so far as we are aware, been made in connection with the dust produced in grinding or polishing industries.

Methods Adopted for Studying Suction Head in Exhaust Pipes and Dust Content of Air.

Before attempting to fix standards of air dustiness we desired to study the relation in actual practice between suction head in exhaust pipes and dust content of the air of the workroom. Our method of procedure was to vary the exhaust pressure at the grinding wheel, measure this pressure in terms of inches of water in a U tube, and then

find the corresponding dust content of the air in the near vicinity of the machine. It is quite evident that under given conditions there must exist a more or less definite exhaust pressure, above which it is impossible to obtain further marked reductions in the dust content of the atmosphere. This quantity of dust may for the want of a better name be called the residual dust content of the air. This dust count (and weight) would probably be a fair standard and would agree closely with the ideas of Lanza and Higgins when they say:

"The most reasonable standard, then, appears to be one based on the quantity of dust that will remain in suspension after the best known methods have been put into use for its abatement."

At the very outset of our work it was agreed that the count of the number of dust particles in each cubic foot of air would not by itself give a complete record of the harmfulness of the dust. It was decided that the following information was essential: Number of particles, distribution by size, weight of dust per cubic foot of air, and the proportion of the dust that was organic or inorganic in nature.

The choice of a sampling method was greatly facilitated by the final report of "The Committee on Standard Methods for the Examination of Air" (1917).

Referring to the Palmer "water spray method," the committee concludes: "This method is a new one and may no doubt be altered and improved in the future. In its present form, however, it has given entirely satisfactory results as tested in the laboratory of three members of the committee. We believe it to be the most promising method now available and recommend that it be used in ordinary sanitary investigations."

In an exhaustive report by Palmer, Coleman, and Ward (1916) we find (p. 1063) under the summary of results with the three sampling methods studies (Graham-Rogers plate, sugar filter, and water-spray methods):

The water-spray apparatus is superior to the sugar filter in—

(*a*) Making possible the collection of larger air samples in the same period of time, with the attendant greater accuracy in the count.

(*b*) Providing a dust sample whose content can be estimated by turbidity and weight as well as by counting.

(*c*) Being more portable.

(*d*) Simplifying and reducing the errors of technique in the substitution of distilled water as the filtering medium for solid soluble material, such as sugar or resorcin, whose dust content is a more variable factor.

And, lastly, Ward (1916), speaking of this same method, says (p. 171):

"It is firmly believed that the new method not only furnishes the simplest and most practical means of determining the dust content in

the air in industrial establishments but that it also gives promise of the most constant results by which the required legal standards may be obtained as a prerequisite to the enforcement of desirable conditions of wholesome air purity in factories, workshops, and mines."

In view of this experience and these recommendations the Palmer water-spray method was chosen by us as the best method to employ.

The technique in the collection and counting of the dust particles followed closely that formulated by the committee on standard methods for the examination of air. In general it was as follows:

The Palmer apparatus was placed in position, 40 cubic centimeters of distilled water was added to the bulb of the machine, and the machine was started. It has been shown by Palmer et al. (1916) (p. 1061) that in a given atmosphere the dust count varies to some degree inversely with the size of the sample, as a result of errors in small samples due to the presence of dust in the water or on the slide. For this reason our samples were practically all of either 250 or 300 cubic feet of air. After each three or four minutes of operation water was added to the bulb to make up that lost by evaporation. At the end of the sampling time the water from the Palmer bulb was drained into an Erlenmeyer flask graduated to 100 cubic centimeters. The bulb was then rinsed with small additional portions of water and these were added to the flask. The total sample was then made up to 100 cubic centimeters. Suitable controls were made with the distilled water used in sampling, which controls received the same laboratory treatment as the dust samples.

When the sample arrived at the laboratory it was thoroughly agitated and two 1-cubic centimeter portions were removed to Sedgwick-Rafter counting cells. These cells were scrupulously cleaned and in most cases were examined empty under the microscope to detect the presence of any adventitious dust. After allowing the cell contents to settle, five counts were made on each cell, one at each corner and one in the center. The lens combination used in the microscope was No. 3 objective, a No. 3 eyepiece with an inserted eyepiece micrometer and a microscope tube length of 166 millimeters. With this magnification, which was approximately 84 diameters; the smallest square ruled on the eyepiece micrometer was found to be 0.02 millimeter on a side, which is the dimension of a "standard unit." In recording the dust count, the particles were grouped by sizes and recorded in counts of the number of particles in each of the following classes.

1. Large masses about 100 standard units (0.04 square millimeter.)
2. About 25 standard units (0.01 square millimeter).
3. About 1 standard unit (0.0004 square millimeter).
4. About ¼ standard unit (0.0001 square millimeter).
5. Dust too fine to count. Presence indicated by a plus (+) sign.

Gravimetric determinations were then made on the remainder of the original sample. The method here consisted in filtering the sample through an ignited and weighed Gooch crucible. The crucible was dried in an oven at 100°–110° for one hour and again weighed. The corrected difference in weight was taken to represent the total weight of the sampled dust. The crucible was then ignited over the bunsen flame and reweighed, the loss in weight being taken as the amount of organic matter present in the original sample.

In all cases a correction was applied for the control analysis. In the microscopic examination this consisted in deducting from the results of the sample analysis the number of particles in each group as found in the control. In the gravimetric analysis the weight of total solids as found in the control was deducted from the solids as found in the sample and any loss in weight on ignition of the control was deducted from that of the sample.

To convert the corrected dust count into the number of particles per cubic foot of air we must first multiply the average count per $\frac{1}{4}$ field by 4 in order to give the average count per total field – 1.0 millimeter × 1.0 millimeter. Since our cell is 1 millimeter deep this count gives the number of particles in a cubic millimeter of our sample. This value must now be multiplied by 1,000 to give the count per cubic centimeter, and again by 100, since the total amount of dust was suspended in 100 cubic centimeters of water. (In a few cases the sample did not contain 100 cubic centimeters and in these the proper figure was used.) It now remains to divide this figure by the total number of cubic feet of air in the sample. Summarizing, we have:

Particles per cubic foot of air = Count per one-fourth field × 400,000 ÷ cubic feet of air in sample.

The U tube used for determining the exhaust pressure was an ordinary piece of glass tubing, bent in the form of a U, attached to one end of which was a piece of rubber tubing. The U tube was filled with water, so colored as to facilitate reading.

The method of determining the U-tube reading was very simple. It consisted in applying to a hole $\frac{1}{8}$ inch in diameter, drilled in the straight portion of the branch exhaust pipe between the machine and the main lateral, the loose end of the rubber tube to which the U tube was fastened. The difference in water level on both sides of the U was then read from a scale fastened to the tube.

Velocity measurements were also made at each machine with an anemometer, so as to determine if possible any correlation between U-tube reading and velocity of air flow.

The exhaust in the principal workroom where these studies were conducted was through a rectangular opening below the wheel. The branch exhaust pipe had a bend just below this opening, and in order to secure a fairly even distribution of velocity over the area where the

measurement was made, we removed the wheel and placed over the exhaust opening a rectangular box the size of the opening and 2 feet high, with top and bottom open, and made our anemometer measurements at the top of this box.

Relation between Suction Head in Exhaust Ducts, Velocity of Flow at Point of Exhaust, and Dust Content of Workroom Air.

Our first studies were carried out in the "Cornering and Light Polishing Shop" of a large small-arms plant, which we shall call "Factory A"; and we desire to express our warm appreciation of the courteous cooperation on the part of the management which made these studies possible.

The "Cornering and Light Polishing Shop" in question is rectangular in shape, 142 feet long by 52 feet wide and 12 feet from floor to ceiling. Ventilation is secured by means of 14 Fenestra windows, 10 by 18 feet. These windows are completely unobstructed by buildings on either side. Natural light in this room is ample, artificial light being used only on dark days.

The operation carried on is that of polishing gun parts and magazine tubes. This is accomplished by holding the piece in close contact with the abrasive wheel and so moving the piece that a smooth polished surface is obtained.

The equipment in this shop consists of five rows of polishing machines mounting approximately 29 wooden wheels, 20 small leather wheels, and 6 belts. Four types of exhaust piping are in use. For polishing magazine tubes a 2 by 6 inch overhead exhaust is used. For polishing large rifle parts a standard down-draft exhaust hood is provided having a 10 by 6 inch throat opening. For the small leather wheel equipment no hoods are used, the exhaust pipe terminating in a 3-inch opening beneath the wheel. For the emery belts a special form of adjustable hood and pipe is employed.

The emery wheels are made by gluing the emery powder (No. 90 is generally used) to the wheel by means of a thin application of glue. When an emery wheel is to be used for the first time, after being freshly coated with emery, it is necessary that all of the loose and large or coarse particles of emery be removed. This is accomplished by means of a piece of metal, or in some cases by the use of a paddle-shaped piece of wood coated with carborundum dust, held firmly against the wheel. This is called truing the wheel. During the polishing process oil must frequently be applied by holding firmly against the wheel an oil-soaked roll of cloth. In the process of polishing gun parts as here performed there are, therefore, in the main three sources of dust:

1. Truing the wheel.
2. Oiling the wheel.
3. Polishing the gun part.

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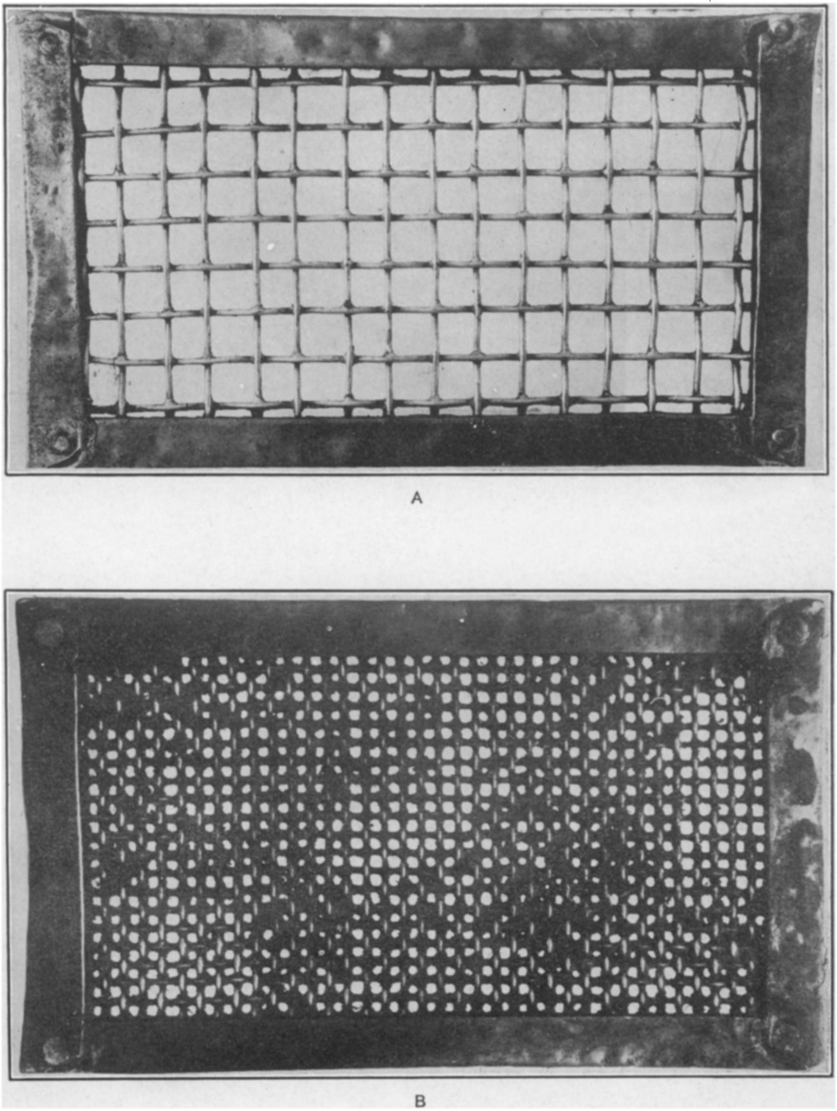


B

Fig. 1.

According to nature and origin the dust may be grouped as follows:

Organic:	Inorganic:
Wood.	Emery.
Cloth.	Metal.
Glue.	Carborundum.
Leather or felt.	

Two rows of machines were selected as being best suited to the purposes of our experiments, one row along the center aisle at the east end of the room and the other row along the north window side of the east end. The operation performed on the window row of machines was that of polishing the magazine tubes, and on the center row that of polishing the trigger guards of the rifles. These two particular rows were selected because they presented the most continuous flow of work and also the most continuous of the grinding operations. The Palmer apparatus was placed midway between two adjoining polishing machines, a position as near a machine as could be obtained without interfering with the work of the operator. The standardization of experimental conditions was exceedingly difficult to obtain, owing to the fact that the work in this shop was of an emergency war nature, and interference with the operators was not to be considered.

Table 1 shows in detail the results of our experimental studies in this shop. (See also fig. 2.)

A second series of similar observations was made in another grinding room of factory A, designated as the heavy polishing shop. This room is rectangular in shape, 249 feet long by 39 feet wide, and 13 feet from floor to ceiling. Ventilation is secured by windows only, of which there are 100.

In this shop the larger parts of the rifles are polished, the method of polishing being exactly the same as that employed, and the abrasive wheels being duplicates of those used, on the two rows of machines studied in the cornering and light polishing shop.

Two rows of machines were selected in this room, four sampling positions being chosen on one row and three on the other. At these seven stations samples were taken coincident with high and low U-tube readings.

In Table 2 are given the results of the experimental observations and analyses in the heavy polishing shop. (See fig. 3.)

It will be noted that the observations were made in pairs. Each pair includes, first, one observation under the normal conditions of operation of the exhaust system, and, second, an observation at the same point after a brief interval (5 to 10 minutes), during which the suction head had been reduced by opening doors in the main exhaust duct between the sampling point and the exhaust fan.

In the miners phthisis prevention committee's report it is stated that "Dr. McCrae found that the dust extracted from the lungs of

deceased miners, by a process of acid oxidation, consisted of extremely minute particles. On measurement, it was ascertained that none of the particles were larger than 12 microns in diameter, and

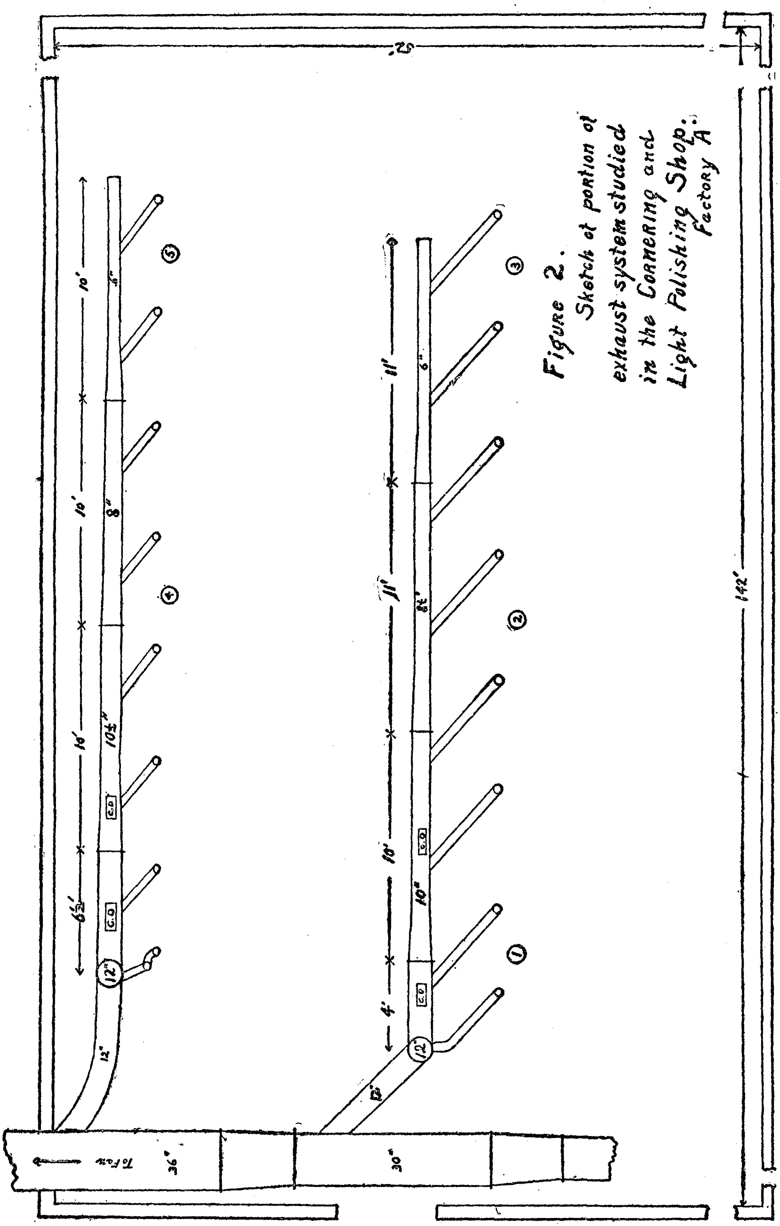


Figure 2. Sketch of portion of exhaust system studied in the Cornering and Light Polishing Shop. Factory "A".

that the great majority of them were less than 1 or 2 microns, or very much smaller in size than a red blood corpuscle.

"These investigations were sufficient to indicate that it is the very fine particles which are the most important factor in the causation of the dis-

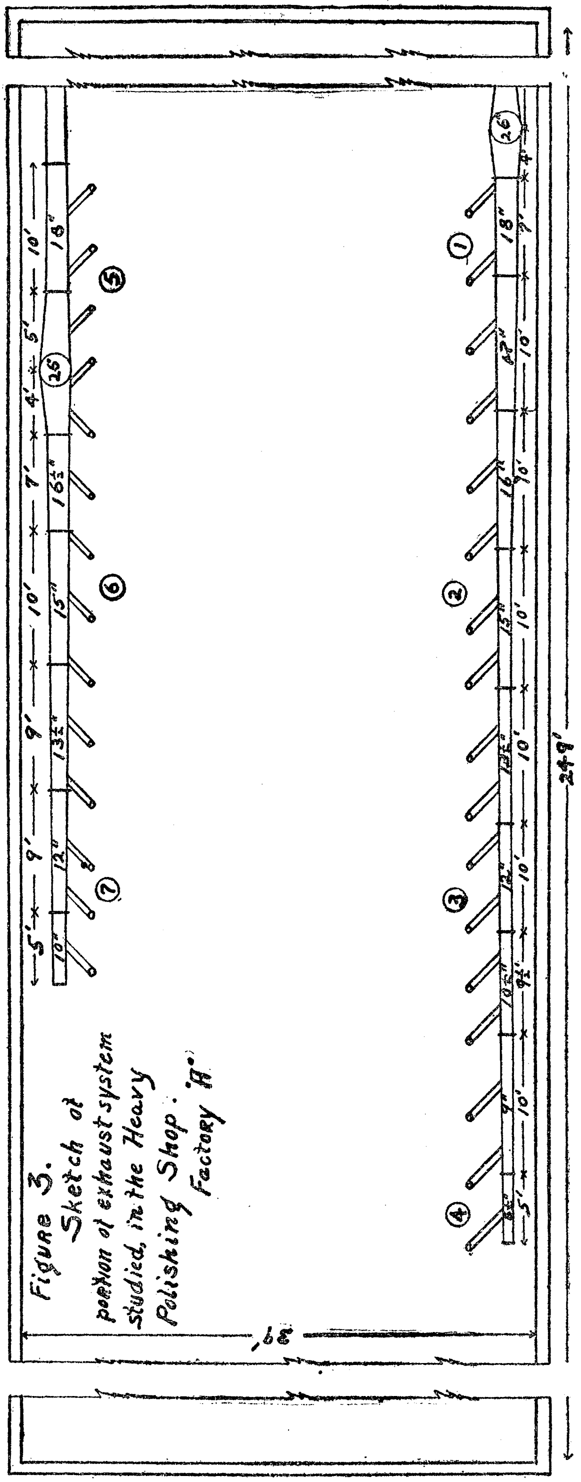


Figure 3. Sketch of portion of exhaust system studied, in the Heavy Polishing Shop: Factory "A"

ease. It is, therefore, very probable that particles over 12 microns in diameter are relatively unimportant, and that only those lying under the limit of 12 microns need be taken into account."

In the light of these conclusions it is evident that the particles which in our study are of greatest interest as disease-producing ones are those classified as ¼ of a standard unit and less in area. One-fourth of a standard unit is equal to 0.0001 square millimeters, or 0.01 × 0.01 millimeters. These particles are, therefore, 10 microns and under in diameter down to, perhaps, 1 or 2 microns, a size which is just countable. It is with these particles that our conclusions will mainly deal.

In Table 3 have been grouped the dust counts of ¼ standard unit particles and the weight of the inorganic dust per cubic foot of air sampled, with the corresponding U-tube readings.

TABLE 1.—*Dust analyses—Cornering and light polishing shop, factory A.*

Sample No.	Date.	Sampling position.	U-tube reading (inches).	Exhaust velocity (fl/min.).	Average number of particles per cubic foot of air.			Total number particles per cubic foot.	Standard units per cubic foot of air.	Milligrams of solids per cubic foot of air.			Per cent inorganic material.
					25 standard units.	1 standard unit.	¼ standard unit.			Total.	Organic.	Inorganic.	
6210	June 21, 1918												
6211		2	3.75	1,470	133	8,940	215,000	224,000	66,400	0.0295	0.0119	0.0176	59.6
6212			.50	432	800	9,310	535,000	545,000	163,000	.0292	.0102	.0190	65.0
6240	June 24, 1918												
6241		3	3.50	1,697	133	3,460	22,400	26,000	10,500	.0105	.0054	.0051	48.5
6242			.25	460	133	12,800	1,773,000	1,790,000	460,000	.0605	.0145	.0460	76.0
6243		1	2.75	1,705	133	2,130	45,200	47,500	15,000	.0098	.0034	.0064	65.3
6244			1.25	1,173		5,320	894,000	899,500	227,000	.0275	.0058	.0217	78.8
6250	June 25, 1918												
6251		5	4.63	4,905		2,420	22,200	24,600	8,000	.0085	.0033	.0052	61.2
6252			.25	1,300		3,270	48,300	51,500	15,400	.0156	.0030	.0126	80.7
6253		4	3.56	4,480		3,840	241,000	245,000	195,000	.0104	.0052	.0052	50.0
6254			.50	1,340	145	4,830	745,000	750,000	195,000	.0193	.0045	.0148	75.6
6260	June 26, 1918												
6261		1	2.62	1,705		3,560	720,000	723,500	183,000	.0193	.0052	.0141	73.1
6262			1.25	1,174		6,250	1,000,000	1,006,000	256,000	.0422	.0134	.0288	68.2
6263		3	3.25	1,682	440	3,270	44,500	48,000	25,400	.0148	.0078	.0070	47.3
6264			.25	461	145	5,550	654,000	660,000	176,000	.0293	.0122	.0171	58.4
6270	June 27, 1918												
6271		2	3.00	1,626	145	5,960	252,000	258,000	72,700	.0422	.0052	.0370	87.7
6272			.25	418	3,700	25,400	790,000	820,000	318,000	.3620	.0000	.3620	100.0

Rate of sampling, 4.5 cubic feet per minute. Volume of sample, between 275 and 301 cubic feet.

TABLE 2.—*Dust analyses—Heavy polishing shop.*

Sample No.	Date.	Sampling position.	U-tube reading (inches).	Average number of particles per cubic foot of air.			Total number of particles per cubic foot.	Standard units per cubic foot of air.	Milligrams of solids per cubic foot of air.			Per cent inorganic material.
				25 standard units.	1 standard unit.	¼ standard unit.			Total.	Organic.	Inorganic.	
7160	July 16, 1918											
7161		1	3.50	160	11,050	854,000	865,210	227,000	0.0672	0.0065	0.0607	90.4
7162			1.50		16,000	1,418,000	1,434,000	363,000	.0382	.0061	.0321	86.4
7163		2	3.00		2,320	70,500	72,820	19,400	.0153	.0030	.0123	80.4
7164			.62		2,080	42,900	44,980	12,150	.0106	.0012	.0094	88.6
7165		3	2.88		1,920	56,800	58,720	15,500	.0130	.0012	.0118	90.7
7166			.62		56,000	2,980,000	3,036,000	768,000	.2120	.0004	.2116	99.7
7170	July 17, 1918											
7171		4	2.62	160	1,760	87,000	88,920	26,900	.0553	.0045	.0508	91.8
7177			.50		3,040	191,000	194,040	50,400	.0102	.0035	.0077	75.5
7180	July 18, 1918											
7181		6	3.25		1,600	130,700	132,300	33,000	.0099	.0017	.0082	82.8
7182			.50		5,600	165,000	170,600	45,400	.0270	.0042	.0228	84.5
7191	July 19, 1918	5	3.50		31,000	180,500	211,500	74,800	.0240	.0062	.0178	74.3
7192			0.00		16,960	1,075,000	1,091,960	285,000	.0748	.0060	.0688	92.0
7193		7	2.38	480	26,750	52,200	79,430	54,400	.0254			
7194			.13	800	13,450	638,000	652,250	191,500	.0802	.0102	.0700	87.2

Rate of sampling, 4.5 cubic feet per minute. Volume of all samples, 250 cubic feet.

TABLE 3.—*Comparative tabulation of number of small dust particles and weight of dust in air with high and low suction heads.*

Sample No.	U-tube reading (inches).	Number of ¼ standard unit particles per cubic foot of air.	Milligrams of solids per cubic foot.	Sample No.	U-tube reading (inches).	Number of ¼ standard unit particles per cubic foot of air.	Milligrams of solids per cubic foot.
6211	3.75	215,000	0.0295	6212	0.50	535,000	0.0292
6241	3.50	22,400	.0105	6242	.25	1,773,000	.0605
6243	2.75	45,200	.0098	6244	1.25	894,000	.0275
6251[1]	4.63	22,200	.0085	6252[1]	.25	48,300	.0156
6253	3.56	241,000	.0104	6254	.50	745,000	.0193
6261	2.62	720,000	.0193	6262	1.25	1,000,000	.0422
6263	3.25	44,500	.0148	6264	.25	654,000	.0293
6271	3.00	252,000	.0422	6272	.25	790,000	.3620
7161	3.50	854,000	.0672	7162	1.50	1,418,000	.0382
7163[2]	3.00	70,000	.0153	7164[2]	.63	42,900	.0106
7165	2.88	56,800	.0130	7166	.63	2,980,000	.2120
7171	2.63	87,000	.0553	7172	.50	191,000	.0102
7181	3.25	130,700	.0099	7182	.50	165,000	.0270
7191	3.50	180,500	.0240	7192	....	1,075,000	.0748
7193	2.38	52,200	.0254	7194	.13	638,000	.0802

[1] Operator worked only 10 minutes. [2] Very light operation.

Figure 4 is a graphical representation of the various dust counts and U-tube readings taken from Table 3.

An examination of Table 3 and figure 4 shows that in general, and other conditions being equal, a reduction in suction head is quickly followed by an increase in air dustiness.

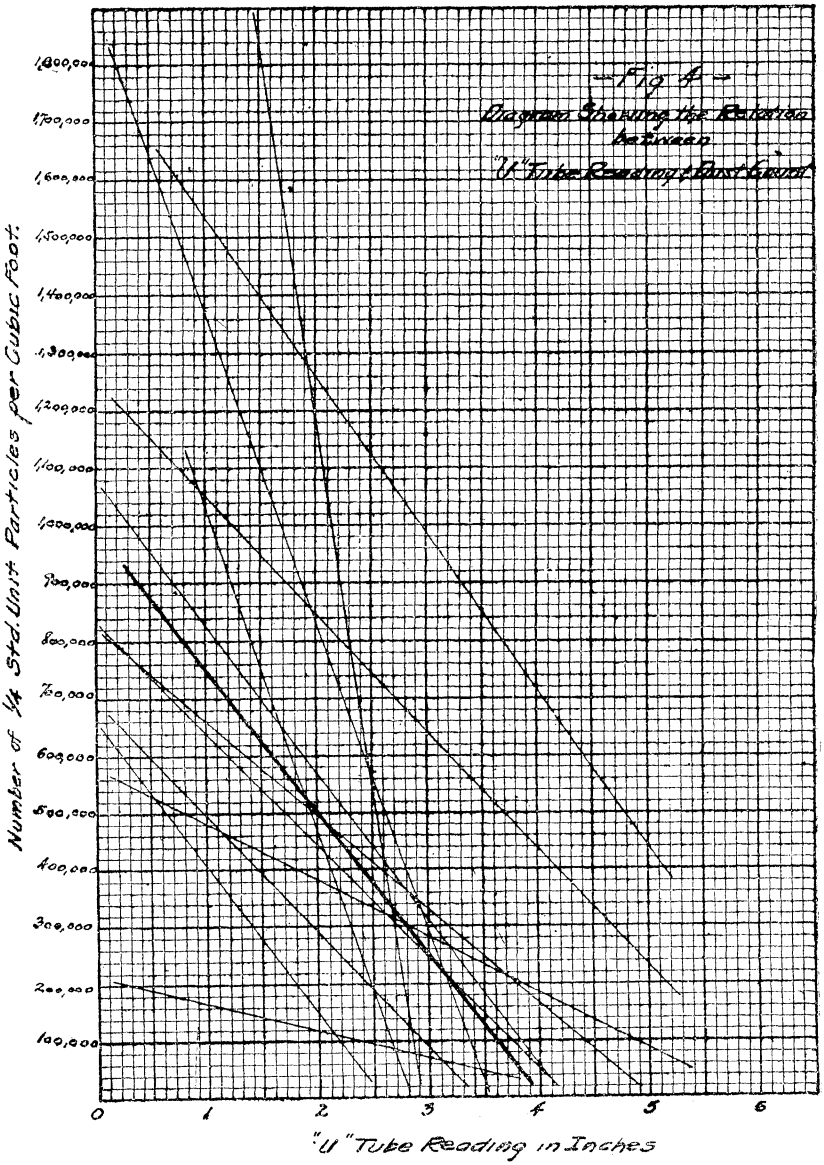
The dust counts with low exhaust pressure are relatively high, varying, with two exceptions, from 165,000 to 2,980,000 particles per cubic foot of air. These two exceptions, samples 6252 and 7164, may be justly eliminated. The dust count on these, being less than 50,000 particles at low exhaust pressure, indicates that, relatively speaking, little dust was being created in the operation. It will be noted that while sampling 6252 the operator only worked 10 minutes of the sampling time, and in the case of sample 7164 the operation was very light. The average of all the dust counts is 853,000 particles, and with the two samples 6252 and 7164 omitted, the average becomes 990,000 or practically 1,000,000 particles per cubic foot of air.

With the application of the normal, higher exhaust pressure the dust content is considerably lower, an average of all the samples being 200,000 particles. In this case there are again two samples, 6261 and 7161, which greatly increase the value of the average. Disregarding these two values the general average becomes 120,000 particles per cubic foot.

The total weight of total solids per cubic foot of air is 0.069 milligrams with the low exhaust pressure (averaging 0.56 inch) and 0.023 milligrams with the high exhaust pressure (averaging 3.21 inches).

An examination of the corresponding observations in the two halves of Table 3 (the normal conditions being on the left, the reduced exhaust velocities on the right) shows more clearly than the general averages just what was happening. In one case (samples 7163

and 7164), where only a very light operation was going on, the reduction of the suction head from 3 to 0.63 inches had no effect on the dust content. In every other instance the dust count went up when the suction was reduced, sometimes only a little—from 720,000 to 1,000,000 (6261-2), or from 854,000 to 1,418,000 (7161-2) or



—Fig 4—
Diagram Showing the Relation between "U" Tube Reading & Dust Count

from 130,700 to 165,000 (7181-2), but usually very markedly. In five instances the count of dust particles increased more than tenfold—from 22,400 to 1,773,000 (6241-2), from 45,200 to 894,000 (6243-4), from 44,500 to 654,000 (6263-4), from 56,800 to 2,980,000 (7165-6), and from 52,200 to 638,000 (7193-4)

It is evident that with the type of wheels used in the two rooms studied, and with the processes carried on there, and with the design of hoods and exhaust ducts in use, a general relation between suction velocity and air dustiness can be deduced which is represented by the heavy line in figure 4. According to this curve we may expect on the average to find over 700,000 small dust particles per cubic foot in the air of such a shop with an exhaust suction head of an inch or less, some 500,000 with a 2-inch head, and some 300,000 with a 3-inch head. Obviously, however, variations in the process or in the construction of the exhaust system will make it quite impossible to extend our deductions as to such a relation beyond the conditions specified.

Conclusions as to Reasonable Standards for Special Ventilation to Control Air Dustiness in a Polishing Shop.

The Massachusetts State Board of Health some years ago laid down the principle that in fixing standards of industrial hygiene it was reasonable to require that conditions should be maintained in any industry approximately equal to those already found in the best plants of that industry in actual operation. On such a basis we may perhaps fairly take the normal conditions in the two admirable polishing shops of factory A as a standard for establishments of a similar type.

It will be noted that in both the cornering and light polishing shop and the heavy polishing shop the suction head normally maintained in the exhaust pipes varied between 2.38 and 4.63 inches and averaged 3.21 inches. Only 5 out of 15 observations fell below 3 inches and only one below 2.5 inches. A fall to 1.25 or 1.50 inches (when the exhaust was reduced for experimental purposes) was at once followed by a marked increase in air dustiness. It would appear from these observations that the 5-inch suction head called for by the Wisconsin Code is unnecessarily severe, while the 2-inch head specified in the New York and New Jersey Codes is a trifle lenient. For an absolute lower limit it is perhaps scarcely possible to go much beyond this figure; but we would suggest that a fairer measure of actual performance would be obtained by specifying that the suction velocity in the exhaust pipes of a polishing shop should at no point fall below 2 inches, and should average 3 inches when measured at a number of different points.

The next point of interest is the linear velocity of suction maintained at the throat of the exhaust duct. This velocity, measured as described on page 433, varied for normal conditions in the cornering and light polishing shop from 1,470 to 4,905 feet per minute and averaged 2,409 feet per minute, while with the lowered exhausts the velocity varied from 418 to 1,340 feet per minute and averaged 845 feet. It would appear, then, that good conditions were main-

tained in this shop when the exhaust velocity at the opening of the exhaust pipe averaged about 2,500 feet per minute, with a minimum of 1,500 feet.

It can not be too strongly emphasized that the relation between suction head in the exhaust pipe and velocity at the wheel—and still more the relation between suction head and air dustiness—will vary widely with other conditions which obtain between the point where the suction head is measured and the wheel itself. We have cited a case in which a clogged screen reduced the linear velocity by nearly one-half; and the whole design of the exhaust system, and particularly of the hood over the wheel, will materially affect the results.

There are five main types of exhaust hoods in the shops which we have studied, as follows:

(1) The underneath type of exhaust hood, which has a 10 by 6 inch opening in the machine table directly under the polishing wheel, which tapers into a 5-inch round pipe connecting with the duct. This hood seems highly efficient, as on account of location and construction it catches practically all of the dust that it is possible to remove.

(2) The overhead type of exhaust, which is a square cast-iron pipe, 2 by 6 inches, with the 6-inch side parallel to the face of the wheel and adjustable. This type of hood would be more efficient if the opening were flared to about 4 by 7 inches, as with the narrow 2-inch opening a quantity of dust escapes into the air, especially if the operator is careless as to the position in which he holds work on the wheel. When this overhead type of exhaust hood is used, there is also a malleable-iron water pan under the wheel to catch dust that is carried past the exhaust hood. In the cornering and light polishing shop the pans are kept filled with water and catch a large amount of dust, but in the heavy polishing shop they are not used, and the majority of the men did not know what they were for.

(3) *The bayonet-shop hoods.*—This hood is used behind wheels on which bayonet blades are polished and sharpened and is a curved hood with flared sides, made of galvanized steel, adjustable to a close position to the wheel or to a distance of 18 inches from the wheel, as the operation may require. The exhaust enters through three narrow vertical openings, running from top to bottom of the hood, the top opening being 2 inches wide at its upper end, the three slits tapering to a width of one-half inch at the bottom of the lower opening. These hoods are probably as good as possible for this type of operation. Their chief drawback is that they offer an increased resistance on account of curved design, with a corresponding drop in the velocity, the velocity at the openings, with a U-tube reading of 3 inches being only 1,200 feet per minute.

(4) *The hoods used on the belt type of polishing machine.*—These are the ordinary type of galvanized steel hood, one over each pulley at each end of the belt, the hoods being tapered to a 5-inch round pipe. These hoods seem satisfactory.

(5) *The common type of galvanized steel hood, as installed by plant workmen without expert supervision.*—It is this type of hood which causes much trouble. In many cases the hoods are practically worthless, due to the fact that the branch pipe connection to the hood is not placed in the proper position to catch dust as it is thrown from the wheel.

It is clear that the efficiency of any of the above hoods depends, not only on the velocity of the exhaust, but also, in large measure, on the proper location of the pipe connection to the hood. The dust from the polishing or grinding operation is thrown from the wheel at a tangent from the point of contact of the piece of work on the

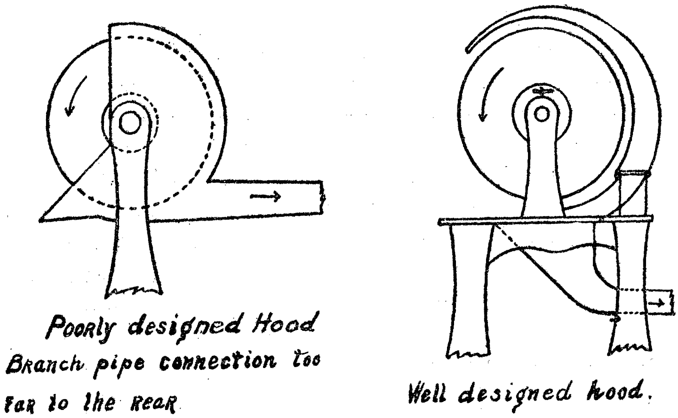


FIGURE 5.

wheel. If the exhaust hood or pipe connection to the hood is not located so that this stream of dust will enter directly into the mouth of the branch pipe, or in the case of the overhead hood, directly into the mouth of the hood, the speed with which this dust is thrown from the wheel will carry it past the exhaust hood or pipe, even though the velocity of exhaust is very high.

Other defects of exhaust systems which we have noticed are (1) the incorrect tapering of main ducts; (2) the use of too many elbows and of elbows of too square an angle; (3) the entering of branch pipes into the main duct at too square an angle.

Such conditions as those cited make it clear that the suction head maintained in the exhaust pipe, and even the linear velocity at its opening, below or above the wheel, can give only an imperfect idea of the actual condition of the shop air as regards dustiness. From the data presented in Tables 1 and 2 it seems possible to

establish tentative standards in regard to the really important condition, the actual dustiness of the air.

First of all, it may be noted that the particles present in the air of the two polishing shops studied were chiefly small particles of the $\frac{1}{4}$ standard unit size (2–10 microns). The average size of all dust particles in 30 samples of air was 0.28 standard unit or 0.00011 square millimeter. In other words, the average particle was close to 5.6 microns in diameter. The average weight of all dust particles in the same 30 samples was a little less than 0.000000086 milligram. The proportion of inorganic matter in the dust of the cornering and light polishing shop averaged 63 per cent; in the dust of the heavy polishing shop, 80 per cent.

The particles as they appeared under the microscope included both steel and emery, the former being in the majority. Particles of both types were almost all sharp and angular and the steel particles were generally of an elongated and jagged form. There were also obvious particles of lint present in the samples.

Turning now (from the standpoint of possible analytical standards) to the figures for the 15 samples taken with normal exhaust conditions, we find the average weight of dust in the air to be only 0.0237 milligram per cubic foot. Of the 15 weights, 3 were under 0.01 milligram, 6 between 0.01 and 0.02 milligram, 3 between 0.02 and 0.04 milligram, 2 between 0.04 and 0.06 milligram, and 1 over 0.06 milligram. We might fairly conclude from these data that the weight of dust in the air of a polishing shop can, with an efficient exhaust system, be kept constantly below 0.06 milligram per cubic foot and should not average over 0.03 milligram. These figures are lower than the standards of 0.14 milligram per cubic foot and 0.28 milligram per cubic foot set, respectively, by the South African commission and by Higgins and Lanza for mine air; but it is obvious that the air of a polishing shop can, and therefore should, be kept freer from dangerous dust than that of a metal mine.

It has been pointed out above that it is the small dust particles which are of chief importance, so that a standard based on the number of $\frac{1}{4}$ standard unit (2–10 microns) particles in the air should prove even more valuable than one based on weight. The average count of the 15 samples collected under normal conditions as previously noted was 200,000 of such small particles per cubic foot. Four samples were under 50,000, 4 between 50,000 and 100,000, 5 between 100,000 and 300,000, and 2 over 300,000. It appears then that the dust content of a polishing shop can be kept generally under 300,000 small $\frac{1}{4}$ standard unit dust particles per cubic foot and should not average over 200,000.

For comparison with the two well-ventilated shops which have been discussed, it may be interesting to cite results of our studies of another small grinding shop in factory A where conditions were much less satisfactory. This shop is a single basement room, approxi-

mately 90 feet long, 36 feet wide, and 9 feet from floor to ceiling. The only means of securing general ventilation is by the door (8 by 8 feet) which opens on the north side of the building. There are six small windows in the room, but these are rarely opened.

The process carried on in this shop is the removal from the forged gun parts and bayonets of the fin which is generally to be found around their perimeter. This is accomplished by holding the forging in close contact with the abrasive wheel and moving it along the surface so that the whole fin is evenly removed. The composition of the metal is in general nickel steel and that portion removed by the abrasive wheel is mainly composed of the oxides of this steel.

The equipment consists of 18 solid grinding wheels mounted in pairs. Two of the wheels have no exhaust hoods, but are equipped with cast-iron guards only. These are wheels of fine texture and used only for very light work. Four of the wheels have hoods but no connection to the exhaust system. The 12 remaining wheels have hoods with a pipe connection at the rear. The suction pressure in the main line of piping, however, varies only from 0 to 1 inch static water pressure, largely as a result of the defective design of the exhaust system. The main duct from the fan to the machines is incorrectly tapered and too many elbows are used between the fan and the dust collector. The last section of the main duct from fan to machines is in this case a 6-inch pipe, and it has four 5-inch pipes with a combined area of 78 square inches connected into it. As the area of the 6-inch duct is only 28 square inches, the velocity of the last branch is zero, and conditions will never be satisfactory until a correctly designed system is installed.

Because of the fact that many different types of parts have to be handled, and also because the size of the fin which is to be removed varies greatly, the amount of dust generated will vary between wide limits. On some classes of work the amount of heavy dust generated is very considerable, but this in many cases does not show in the results of the analyses because such dust rapidly drops to the floor of the workroom.

TABLE 4.—*Dust determinations—Rough forge grinding shop, factory A.*

Sample No.	Sampling position.	Average number of particles per cubic foot of air, by sizes.			Total number of particles per cubic foot of air.	Standard units per cubic foot of air.	Solids per cubic foot of air (mgs./cu. ft.).
		25 standard units.	1 standard unit.	¼ standard unit.			
6101	1	....	5,800	104,200	110,000	31,100	0.024
6102	2	....	11,000	193,000	204,000	59,000	.048
6132	2	....	19,000	455,000	474,000	132,000	.245
6131	1	....	21,000	327,000	348,000	102,000	.286
6201	2	....	30,300	529,000	560,000	181,000	.505
6202	3	....	36,000	509,000	540,000	170,000	.341

Rate of sampling, 4.5 and 4 cubic feet per minute, respectively. Volume of air samples, 112-160 and 301.5 cubic feet.

The results of the experimental observations are shown in Table 4. It will be noted that the $\frac{1}{4}$ standard unit particles which are of greatest interest range in number from 100,000 to 500,000, the average being 352,000. With regard to the weight of the dust per cubic foot of air, the values range from 0.024 to 0.505 per cubic foot, the average being 241 milligrams per cubic foot. Only two samples were analyzed for the nature of the dust, 6201 and 6208. These showed that over 99 per cent of the dust was of inorganic nature.

The failure to comply with the standards suggested on page 445 is evidently due in this instance to obvious defects in the exhaust system, and it is clear that such a system as that at present installed should be radically reconstructed.

Observations in Regard to Air Dustiness in the Sand-blasting Room of Factory A.

It is obvious that different standards of air dustiness must be worked out for various industrial processes by a study of conditions actually maintained in well-operated shops. It may be of interest, however, to present here certain data obtained in a section of a workshop in factory A used for sand blasting.

The equipment consists of five sand-blasting cabinets, in which the operation is performed by passing the arms through open portholes in the cabinet and holding the object to be cleaned in the path of the sand blast, the operator guiding his movements by looking through a window in the face of the cabinet.

The dust in the air of this shop may arise from—

1. The agitation of the heaps of sand on the floor of the room.
2. The escape of sand through the porthole around the arm of the operator.

Table 5 shows the results of the analysis of samples of air in front of the sand-blasting cabinets. From this table it may easily be seen that the dust counts of $\frac{1}{4}$ standard unit particles are very large, varying from 400,000 to 3,000,000, the average being 1,510,000, the weights of dust per cubic foot of air varying from 0.31 to 0.93 milligrams per cubic foot, and it will be observed that the dust is 97 per cent inorganic material.

In such a workshop as this we believe that if the floor were kept free from sand piles (the sand being stored in a covered bin), if the floor adjacent to the cabinets were kept sprinkled with water, and above all if the portholes opening into the cabinets were protected by tight sleeves through which the arm of the operator were passed, the air could be kept reasonably free from dust, probably well within the limits suggested for polishing shops.

TABLE 5.—*Dust determinations—Sand blasting shop, Factory A.*

Sample No.	Date.	Sampling position.	Average number of particles per cubic foot of air, by sizes.			Total number particles per cubic foot of air.	Standard units per cubic foot of air.	Solids per cubic foot of air (mgs./cu. ft.).			Per cent of inorganic matter.
			25 standard units.	1 standard unit.	¼ standard unit.			Total.	Organic.	Inorganic.	
6140	June 14, 1918	Control									
6141		Machines 1 and 2	267	46,300	431,500	478,050	161,000	0.3175	0.0008	0.309	97.4
6142		Machines 2 and 4	267	79,500	715,000	794,767	262,000	.6070	.0015	.592	97.5
760	July 6, 1918	Control									
761		Machines 3 and 4		136,000	3,220,000	3,356,000	744,000	.9360	.0024	.9100	97.2
7100	July 10, 1918	Control									
7121		Machines 1 and 2		82,500	1,427,000	1,429,500	437,000	.6450	.0019	.6260	97.1

Rate of sampling 4.5 cubic feet per minute. Volume of samples, 250 and 300 cubic feet.

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A PRACTICAL TRAINING COURSE IN PUBLIC HEALTH ADMINISTRATION.

Preliminary announcement is made by the public health committee of the New York Academy of Medicine and the New York Bureau of Municipal Research of a practical training course in public health administration to be conducted jointly by these two agencies in New York City during the coming spring. The contemplated course will cover a period of six weeks beginning April 30, 1919. The first three weeks of the course will be devoted to lecture-conferences conducted by public health experts of national reputation, and the last three weeks to field study and observation of health work and institutions in and about New York City. No persons will be enrolled for the course who can not give assurance of attendance for at least the first three weeks of the course. The last three weeks of practical field study is, however, optional. During the first three weeks, a day or the major part of a day will be given to a lecture-conference on each topic of the program, sessions of the course being held daily except Sunday from 10 a. m. to 12 m. and from 2 to 4 p. m. A fee of $25 will be required of all students enrolling for the course.

The aim of the sponsors for this training course is to make it possible for the busy health executive to come in contact with the leaders of public health thought and action in the United States, and through such contact to acquire, for use in his own work, new ideas